before and after admission as a function of total cardiac admissions (range = 0 to > 6) per day.

Subsequent analyses were completed to discern additional potential recondite relationships between snowfall and heart failure. Appropriate ancillary analyses were completed when violations of statistical assumptions occurred. Inspection of the results indicated that monthly variations over the entire year for both total cardiac admissions and snowfall might be useful; consequently, these data were obtained from the major file. (All analyses involved SPSSX software on a VAX 4000 computer.)

## Results

Although there were no statistically significant differences between any of the five months for mean numbers of daily admissions of myocardial infarction, transient symptoms, or total admissions per day for the 4 years of this study, the mean daily snowfall displayed the expected seasonal effect, $F(4, 600) = 5.84$, $p < .001$, $\eta = .20$, for this region. The mean daily snowfall for each month across 4 years was as follows: November, 0.7 cm ($SD = 1.8$); December, 2.8 cm ($SD = 3.8$); January, 1.7 cm ($SD = 2.8$); February, 1.8 cm ($SD = 4.2$); and March, 1.6 cm ($SD = 3.8$).

Table 2 shows the lag/lead Spearman correlations between myocardial infarctions, transient symptoms, total admissions, and snowfall for the day of and the days before and after admission; there were no statistically significant ($p < .01$) correlations. There were weak but statistically significant positive correlations between the number of blue code and congestive heart failure cases and the amount of snowfall on the day of admission.

**TABLE 2**
**Correlations Between Daily Admissions for Various Acute Cardiac Disorders and Snowfall on the Day of and the Days Before and After Admission**

| Lag/lead[a] | Total admissions | Myocardial infarction | Transient symptoms | Congestive heart failure | Blue code |
|---|---|---|---|---|---|
| −3 | −.03 | .04 | −.05 | −.04 | −.01 |
| −2 | −.02 | .02 | −.06 | .06 | −.04 |
| −1 | −.04 | .00 | −.03 | .02 | .01 |
| 0 | −.02 | −.07 | .02 | .12* | .15* |
| 1 | .03 | .00 | .03 | .00 | .04 |
| 2 | −.02 | .02 | −.06 | .02 | .08 |
| 3 | −.02 | −.04 | .00 | .01 | .05 |

[a]Number of days before or after snowfall.

*$p < .01$.

**TABLE 1**
**Means and Standard Deviations for Number of Admissions per Day for All Major Diagnostic Categories of Heart Dysfunction**

| Categories | *M* | *SD* | Range | % of total cases |
|---|---|---|---|---|
| Angina | 0.5 | 0.7 | 0–3 | 19 |
| Chest pain | 0.4 | 0.7 | 0–3 | 18 |
| Posterior myocardial infarction | 0.3 | 0.6 | 0–4 | 14 |
| Myocardial infarction | 0.3 | 0.5 | 0–2 | 13 |
| Inferior myocardial infarction | 0.3 | 0.5 | 0–2 | 10 |
| Anterior myocardial infarction | 0.2 | 0.4 | 0–3 | 7 |
| Congestive heart failure | 0.1 | 0.3 | 0–2 | 4 |
| Arterial fibrilation | 0.1 | 0.3 | 0–2 | 3 |
| Blue code | — | — | 0–1 | 2 |
| Heart block | — | — | 0–1 | 2 |
| Arrythmia | — | — | 0–2 | 2 |
| Other | — | — | 0–1 | 6 |

1454) = 55.45, $p < .001$. The mean stay in the hospital was 4.2 days ($SD$ = 3.2; range = 0–29 days); the mortality for patients who were admitted for cardiac emergencies was 8.7%.

Both parametric (Pearson $r$) and nonparametric (Spearman $\rho$) correlations were calculated between the number of admissions per day for each diagnostic category and the two major clusters of categories and for the snowfall per day for the day of admission and for each of the 3 days before and after admission. The two major diagnostic clusters were *myocardial infarction* (the sum of inferior, posterior, anterior, and general myocardial infarctions) and *transient symptoms* (angina and chest pain). The two clusters respectively constituted 44% and 37% of all cases. Correlations between number of emergency admissions and snowfall for the days before and after the admissions were completed by utilizing the appropriate lags in order to perform a symmetrical lag/lead analysis.

To ensure that any possible relationship between extreme snowfall and number of cardiac admissions was not masked by the size of the database, we conducted the following analyses: (a) Correlations were calculated separately for total cardiac admissions on each day of the week; (b) one-way analyses of variance (ANOVAs) were completed for number of admissions on the day of and for each of the 3 days before and after days in which the snowfall was nil (320 days), 1.0 to 1.9 standard deviations above average (55 days), 2 to 2.9 standard deviations above average (21 days), and more than 3 standard deviations above average (19 days); and (c) one-way ANOVAs were completed for the amount of snowfall on the day of admission and for each of the 3 days

ies, professionals too tend to remember episodes that support the myth and to forget episodes that do not support the myth, even when their own records demonstrate no effect.

Although observation is considered the cornerstone of the scientific method, there can be significant distortion by post hoc rationalization and by the belief systems of the observer. Variable intervals of reinforcement for any response are difficult to extinguish. Consequently, only intermittent agreement between the expectancy or belief and the occurrence of aversive environmental events is required to maintain the belief. This artifact was clearly evident for people who believed in the 23-day, 28-day, and 33-day fixed biorhythm theory. Even though the numbers of so-called critical days and incidence of industrial accidents occurred at chance expectancy, the beliefs were still maintained (Persinger, Cooke, & Janes, 1978).

A relationship between snowfall and heart attack is a popular belief in northern Ontario. The ostensible mechanism, which appeals to common sense, is that a heavy snowfall requires significant mechanical stress (shoveling), which results in heart attacks. In one unpublished survey of 150 first-year university students, 83% of the respondents reported that they believed that snow shoveling produced heart attacks.

The region of Sudbury, Ontario contains a population of approximately 100,000 people. We reasoned that if a strong causal relationship existed between this stimulus (snowfall) and response (heart attacks), a statistical increase in heart failures should be evident even though we could not determine the actual incidence of snow shoveling. Consequently, we decided to test this hypothesis during the period before snow shoveling had been replaced significantly by the utilization of snow removal machines.

## Method

All admissions for cardiac emergencies during November through March for the years 1983 through 1986 (4 years) to the three local hospitals within the Sudbury Basin were obtained (by Susan E. Ballance); these months contained 93% of the total snowfall for the 4 years. The date of admission, sex, age, and admission diagnosis were obtained for each patient. The means and standard deviations for the number of admissions per day for each of the major diagnostic categories for the 1,456 admissions during the 605 days that constituted our observation period are shown in Table 1. The relative percentage of cases within the diagnostic categories are also shown. For comparison, the snowfall parameters for this period were as follows: mean snowfall per day = 1.7 cm; $SD$ = 3.5 cm; range = 0–26 cm; and total snowfall = 1,043 cm.

The admission population was 68.7% men and 31.3% women; the average age for men at the time of admission was 58.1 years ($SD$ = 12.8), and for women, it was 63.3 years ($SD$ = 12.7), a significant difference, $F(1,$

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# Snow Fall and Heart Attacks

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ABSTRACT. Total numbers of daily hospital admissions for cardiac emergencies were obtained from 3 hospitals within the Sudbury Basin in Canada for November through March for each of 4 consecutive years (1983–1986). Major diagnostic categories were also differentiated. No statistically significant correlations were found between the amount of snowfall during the day of or the days before or after admissions for the major categories of cardiac emergency. Specific analyses, conducted to reveal possible recondite associations between extreme or cumulative snowfalls and the most extreme days of cardiac emergencies, indicated a chance association. We conclude that the occurrence of heart attacks is independent of snowfall but that, when they occur, they are attributed to shoveling if there has been a recent major snow storm.

POPULAR MYTHOLOGY contains explanations by which people who share these beliefs rationalize unexpected or traumatic events. When an event occurs that is commensurate with the belief, it is reinforced. When an event occurs that is not commensurate with the belief, the refuting observations are forgotten or ignored, and the explanation is not evoked. The belief that extreme numbers of aberrant social behaviors occur during the full moon is a classic example (Persinger, 1980). Dozens of methodologically sound studies have failed to show effect sizes that would warrant the prevalence of the belief. As stated by Cluver, Rotton, and Kelly (1988), who reviewed these stud-

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**TABLE 3**
**Means and Standard Deviations for Total Daily Cardiac Admissions on the Day of and the Days Before and After Snowfall**

| | Amount of Snowfall | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 1 *SD* | | 2 *SD* | | 3 *SD* | | |
| Lag/lead[a] | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *F*(3, 60) |
| 3 | 2.4 | 1.5 | 2.0 | 1.4 | 2.1 | 1.7 | 2.6 | 1.5 | 1.88 |
| 2 | 2.4 | 1.5 | 2.2 | 1.5 | 2.8 | 1.2 | 2.5 | 1.6 | 0.81 |
| 1 | 2.4 | 1.5 | 2.5 | 1.4 | 2.8 | 1.7 | 1.9 | 1.0 | 1.14 |
| 0 | 2.4 | 1.5 | 2.1 | 1.2 | 2.6 | 1.7 | 2.6 | 1.3 | 0.82 |
| −1 | 2.5 | 1.5 | 2.1 | 1.2 | 2.6 | 1.7 | 2.7 | 1.9 | 1.24 |
| −2 | 2.4 | 1.5 | 2.6 | 1.3 | 2.5 | 1.3 | 2.0 | 1.8 | 0.75 |
| −3 | 2.4 | 1.4 | 2.5 | 1.4 | 2.1 | 1.8 | 2.7 | 2.1 | 0.70 |

[a]Number of days before or after snowfall.

Correlation analyses between the total number of myocardial-infarction and transient-symptom admissions on each day of the week and the snowfall during or around these days yielded only two significant values. The number of admissions for myocardial infarctions on Tuesdays was negatively associated ($-.24$, $p < .01$) with snowfall. The number of admissions for transient symptoms was negatively correlated ($-.26$, $p < .01$) with snowfall on the same day for Saturdays only. There was no conspicuous day-of-the-week facilitation of the relation between any other type of cardiac admission and snowfall.

Table 3 shows the means and standard deviations for the daily number of total cardiac admissions for each of the 3 days before and the days on which snowfall was 0, more than 1 but less than 2 standard deviations above the mean, more than 2 but less than 3 standard deviations above the mean, and more than 3 standard deviations above the mean. Successive ANOVAs demonstrated no statistically significant differences between the number of admissions on the key days surrounding the different amounts of snowfall.

Table 4 is the orthogonal presentation of the data. It shows the means and standard deviations for the amount of snowfall (in centimeters) for each of the 3 days before and the day on which there was 0, 1, 2, 3, 4, 5, or 6 or more total emergency cardiac admissions. Although lags for snowfall up to seven days before the key day were calculated, this interval (3 days) showed the only, although weak, effect. The only significant difference, $F(6, 598) = 3.15$, $p < .01$, occurred for snowfall 3 days before admission. A posteriori analysis (Tukey's set at $p = .05$) indicated that the major source of the difference was due to days on which the maximum number of patients ($n > 5$) were

**TABLE 4**
**Mean Snowfall on the Day of and on Each of the Three Days Preceding Admission as a Function of the Number of Total Cardiac Admissions per Day**

| No. of admissions | No. of days | Lag[a] 0 | | −1 | | −2 | | −3 | |
|---|---|---|---|---|---|---|---|---|---|
| | | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| 0 | 51 | 1.6 | 2.5 | 2.1 | 4.5 | 2.0 | 4.7 | $1.5_a$ | 3.2 |
| 1 | 124 | 1.7 | 3.7 | 1.7 | 3.6 | 1.8 | 3.1 | $2.3_a$ | 4.2 |
| 2 | 158 | 1.9 | 3.2 | 1.8 | 3.0 | 1.8 | 3.7 | $1.4_a$ | 3.2 |
| 3 | 148 | 1.6 | 3.9 | 1.2 | 2.1 | 1.3 | 2.2 | $1.5_a$ | 2.9 |
| 4 | 80 | 1.8 | 3.5 | 2.4 | 4.7 | 2.0 | 4.1 | $1.7_a$ | 2.9 |
| 5 | 25 | 1.1 | 2.0 | 0.6 | 1.4 | 0.7 | 2.0 | $0.6_a$ | 1.3 |
| >6 | 20 | 1.2 | 3.0 | 2.9 | 5.2 | 2.4 | 4.6 | $4.1_b$ | 6.1 |

*Note.* Within columns, means with different subscripts differ significantly.

[a]Number of days preceding admission.

admitted. For these days (20 of 605 days), snowfall was 2 to 4 times heavier than it was on days on which the number of admissions was less than 6 or more per day. There was significant heterogeneity of variance (Bartlett's Box ranged from 4.56 to 12.79) in snowfall for all days (0 and lagged) with different numbers of cardiac admissions; however, nonparametric tests (Kruskal–Wallis) confirmed only the contribution of snowfall for 3 days prior to admission, $\chi^2$ (6, $N$ = 605) = 9.24, $p < .01$.

Because of the significant heterogeneity of variance for the snowfall 3 days before the day of admission, we listed these days to discern the source of the heterogeneity. Analyses indicated that the discrepancy was due to 3 (of the 20) days during which extreme (> 14.9 cm) snowfall had occurred. There were a total of 15 days out of the 605 days included in this study in which the amount of snowfall exceeded 14.9 cm; the remaining 12 days with extreme snowfall occurred 3 days before 0, 1, or 2 admissions. Chi-square analysis of the number of days with either less than or greater than this amount of snowfall and the seven admission categories indicated a significant discrepancy in proportion, $\chi^2$ (6, $N$ = 605) = 18.07, $p$ = .006.

The preceding analysis implicitly assumed that successive days were independent of each other and that daily increments of analysis would be optimal to discern any potential relationship between the total amount of snowfall and emergency cardiac admissions. It is possible that this association may only be obvious when the total number of admissions during the complete 3-day intervals after an extreme snowfall are considered.

To test this, we extracted for the entire 4-year period (a) the 10 days in which the largest single daily snowfall occurred (between 13 cm and 26 cm), (b) the 10 quads of 4 successive days that showed the greatest snowfall (between 14 cm and 69 cm), and (c) the days for which there had been no snowfall for at least 4 days before and after ($n = 10$). The number of these days in each year were no less than 2 and no more than 4.

The total number of cardiac admissions for the day of snowfall and for each of the subsequent days were added, starting from the day of the single largest snowfall for the first cluster and on the fourth day of the quad; the latter was calculated to discern potential cumulative effects of continuous moderate snowfall. The sum of these total admissions over 3 days for each of the three clusters was called the *postevent measure*. Similarly, the total number of cardiac admissions for the 3-day interval before the single snowfall, the 4th day of the quad, and before the reference day for the no-snow interval were called the *pre-event measures*.

Repeated measures ANOVA was performed between the pre-event and postevent measures of total cardiac admissions and the three groups of snowfall categories. The means for total admissions ranged from 7.7 to 8.1 (*SD*s ranged from 1.7 to 3.7, respectively). The results indicated no statistically significant differences between total numbers of emergency cardiac admissions during the three clusters of extreme snowfall, $F(2, 27) = 0.11$, $p > .05$, or between the intervals before or after the key days, $F(1, 27) = 0.05$, $p > .05$. There was also no statistically significant interaction between before and after measures and the three types of snowfall intervals, $F(2, 27) = 0.0$, $p > .05$.

To minimize the likelihood that a cardiac–snowfall connection might emerge only within a seasonal perspective, ANOVAs were completed for snowfall as a function of each month of the year and for the number of daily total cardiac emergency admissions as a function of each month. Although there were no statistically significant differences in the number of daily admissions for heart emergencies, $F(11, 1449) = 1.48$, $p > .05$, the expected monthly differences in snowfall were observed, $F(11, 1449) = 22.38$, $p < .001$. There were a total of 3,500 admissions during the 4 years studied.

## Discussion

The results of this analysis, which involved a complete population of emergency cardiac admissions within a city of approximately 100,000 people, indicated no statistically significant association between either the occurrence or the amount of snowfall and major classes of acute cardiac failure. The absence of statistically significant correlations between the number of daily emergency admissions and snowfall during the previous 1 to 3 days minimizes the likelihood of delayed effects.

When large samples are used, strong relationships between extreme values of a stimulus and a response can be masked by the average. We minimized the possibility that a relationship was hidden within days associated with extreme values in either snowfall or emergency admissions by analyzing those days separately. There was no evidence either of a strong association or of one that was a systematic function of the amount of snowfall.

As emphasized repeatedly by Lebowitz (1973), weather phases are not easily reduced to daily increments of analysis. To ensure that we had included the optimal increment of analysis, we used epoch analyses to include all emergency admissions that occurred in the days before or after the most extreme snowfalls. Again there was no evidence of a relationship. The greatest numbers of daily cardiac admissions were as frequent when there had been no snowfall for several days as when there had been major snowfalls. Even inclusion of consecutive days in which there was cumulative snowfall did not reveal a clear cardiac connection.

The major result involved the statistically significant and marked variance in snowfall during the days that preceded those days on which the maximum number of cardiac admissions occurred. Inspection of the data indicated that the heterogeneity of variance was due to only 3 of the 20 maximum cardiac admission days, in which there had been snowfalls that exceeded 14.9 cm. The remaining 12 days on which snowfall had exceeded this value had occurred 3 days before 0, 1, or 2 admissions. Because the number of days with 0, 1, or 2 cardiac admissions was so large ($n$ = 51, 124, and 158, respectively), these extreme snowfall values did not affect the variability.

Even though the disproportionate number of extreme snowfalls occurring 3 days before the heaviest admissions was statistically significant, the magnitude of the effect, considering the number of cases (i.e., 605 days), is trivial. According to attribution theory (Heider, 1958; Kelly, 1967), people, including medical professionals, attempt to understand, predict, and control events—especially those that are anxiogenic and uncertain. The belief that one can, to some degree, predict or explain sudden "epidemics" of cardiac admissions might provide the professional with a greater perception of control.

Remembering those days in which the largest numbers of cardiac admissions were preceded by extreme snowfalls would be compatible with an attempt to maintain a sense of control and predictability. That only 3 of the 20 maximum cardiac admission days were in fact associated with extreme snowfall suggests that very few confirming observations are required to maintain such a belief or explanation. Such occasional and intermittent association is expected for beliefs that are maintained by variable interval schedules of confirmation.

On the other hand, extreme snowfalls during or preceding less memorable days for cardiac emergency would not be remembered because they

emergencies is likely because the annual incidence is comparable to that found in other samples. The age range for 97.5% of the cardiac emergency population was above 32 years of age for men and above 37 years for women. According to the 1980 census for the region, the number of people within that age range is approximately 35,000 or 56,000 (depending on the inclusion of nearby towns). The mean number of admissions per year was 880. Because death occurred in 9% of that population, the annual incidence of cardiac-related death would have been 141 and 226 per 100,000, which is within the expected range.

We cannot exclude the possibility that a snowfall effect would have been evident if we had examined only the 9% of the patients who died. A specific effect of snowfall on these patients would implicate a premorbid condition that was simply triggered by the shoveling or was somehow particularly vulnerable to mechanical activity. Even a moderately strong correlation between fatal heart failures and snowfall would have been masked by the number of nonfatal cardiac admissions.

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would not be commensurate with the attribution or the belief. Even though just as many extreme snowfalls occurred before days in which the admission rates were much lower (either 0, 1, or 2), the significance would be lost in both the magnitude and mundanity of the days with these rates. In other words, the occurrence of extreme snowfalls on 1 of every 20 days of minimum cardiac admissions would not be sufficient to extinguish or refute the belief. Weak effects as intermittent reinforcers of belief have been reported elsewhere. Wilson and Tobacyk (1990) found that crisis center workers believed lunar phases were associated with the number of telephone calls they received, despite the fact that not more than 3% and most likely less than 1% of the variance was accommodated by 28–30-day cycles.

There were two classes of emergency cardiac admissions that could support the snowfall–snow shoveling hypothesis. As noted in Table 2, there were weak ($p < .05$) but statistically significant positive correlations between the amount of snowfall and admissions for congestive heart failure and blue code conditions. Although it is possible that snowfall influences only these diagnostic subtypes (which may have an anomalous psychological impact on attending professionals), this possibility requires replication with additional samples and within other districts.

There are several limitations to our explanation. First, we did not measure the actual number of people who had been shoveling snow before their emergency admissions. No significant correlation between snowfall, snow shoveling, and heart attacks would be expected if the vulnerable population did not shovel snow. Because more than 50% of our population were 50 years of age or older, it is possible that grandchildren or young neighbors performed the task. Considering the demographic and cultural background of the residents, this option appears unlikely.

Although we did not measure the percentage of people within the vulnerable ages who actually shoveled snow, random samples of observations during the 12 hr after two significant snowfalls indicated that approximately 60% of Sudbury residents shoveled snow. If this is generalizable to other snowfalls, then shoveling would be a common sequelae to these events. Considering the number of days included in this analysis, only a 10% increase in the mean variance in cardiac admissions would have been sufficient to generate statistical significance. This means that only one or two extra cardiac admissions on the day of and the day after a snowfall for the 30 days with the most precipitation within a population of 100,000 people would have been sufficient. The analysis indicated that this association did not occur.

Certainly the strongest argument against a significant effect from snowfall per se is the absence of statistical significance for comparisons of daily cardiac admissions when all 12 months were considered. These results suggest that cardiac admissions, at least in Sudbury, occur independently of major seasonal factors. That the Sudbury sample is representative of cardiac